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The Cork Airport Roof

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Summary

The Cork Airport Terminal Development [1] represents a design driven by the desire for an innovative structure delivering high functionality, light and a spatial quality rare in regional airports.

This paper provides an overview of the design and construction of the roof of the Terminal Building and the utilisation of innovative design techniques.

1. Introduction

1.1 History of Cork Airport

Cork Airport was founded by the Irish Government in 1957. Passenger numbers traveling through Cork Airport had been increasing steadily during the 1980's and 1990's. Figures in the late 1990's were showing that throughput had started to escalate more rapidly than originally envisaged and the Airport Authority realised that investment in Cork Airport was needed immediately. As a result, the Airport Authority commissioned a masterplan to examine redevelopment through to 2010. The Masterplan reviewed all aspects of Cork Airport infrastructure and recommended a phased terminal development. This included the construction of a new terminal building. Jacobs was appointed in April 2001 to take forward the masterplan and develop a design brief and planning application. HOK were appointed as Specialist Aviation Consultants and Buro Happold as Specialist Structural Consultants for the New Terminal Building Roof.

2. Concept for the Airport

The key design concepts set for the new terminal were:

- a fluid and logical progression from car or public transport to the plane
- transparency landside / airside.
- the use of natural materials in their natural state
- longevity and low maintenance
- Use of the existing ground profile to define public and restricted zones around the site and within the building
- Ability to expand to 5 million passengers per annum.

The design was developed closely with the Airport Authority through workgroups

3. Terminal Building Roof

3.1 Roof Inception

The structural concept for the new Terminal Building roof originated during the course of a design competition as a lightweight marriage of timber and steel to present a minimal expressed structure for

very long spans of up to 40 metres ((Fig. 1). The roof structure helps to define the iconography of Cork Airport as a unique and desirable destination for air travellers.

3.2 Concept Design



Fig. 1 Design concept

The form of the roof arose in response to structural and Architectural design criteria. Among these, those more apparently manifested in the final structure of the roof include robustness, way finding, sustainability and iconography.

In general terms, the roof covering is a steel deck supported on a grillage of steel beams which span between pairs of bowstring beams of glue laminated timber and steel tie rods held apart by steel compression struts.

The beams are stiffened by steel rods which lie below the beams in the span and above at the supports to create bowstring trusses which are in turn supported on steel arms, which spring from the tops of the columns. (Fig 2)

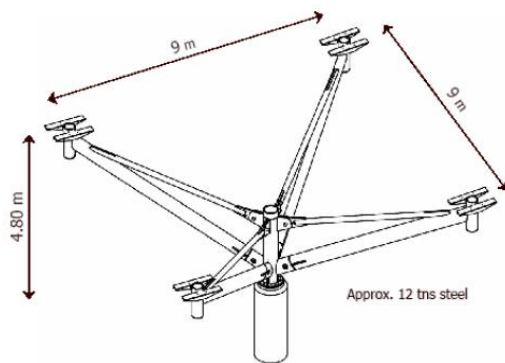


Fig. 2 Steel Fingers / Tree

The columns are spaced at 18 metres centres along the length of the building, the pairs of glulam beams are at 9 metre centres.

The roof is 175m long x 84.5m wide (Fig. 3).

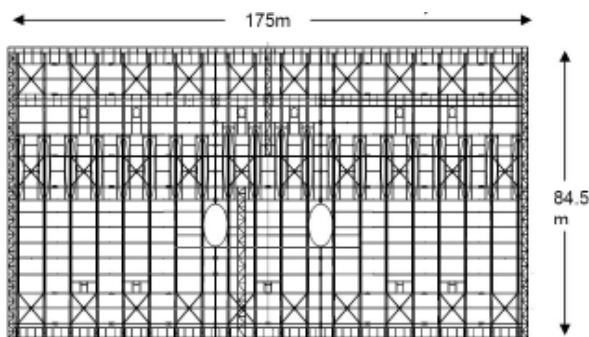
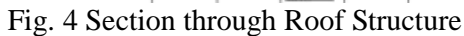


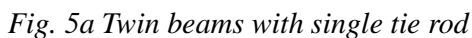
Fig. 3 - Roof Framing Plan

The sweep of the roof is lower over the entrance lobby and check in area, rising higher to airside to accommodate retail and lounge facilities at an upper level (Fig. 4). The form delivers natural day lighting on all four sides as well as the central roof lights and provides the departing passengers a clear sense of direction. The direction of the bowstring beams assist in way finding, providing visual cues to departing passengers. Arrayed parallel to the departure process, they point the way through check-in and security to the airside departures area.

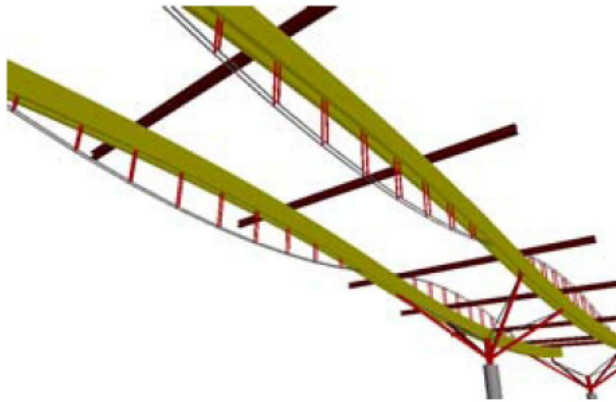
The roof form also aims to strike a sustainable balance between minimising the enclosed volume while creating a spacious and attractive facility that air travelers will want to use. Minimising the enclosed volume means lower capital and running costs and this needed to be balanced against the important features of spaciousness and design quality to generate positive associations with the facility and help reinforce a memorable experience of Cork Airport as a unique national gateway.



3.3.1 Design Process



High strength glue laminated timber was selected for efficiency from sustainably managed European sources. Because it is built up of many layers of strength graded timber, much of the uncertainty associated with an individual lam or of particular flaws associated with single timber element is eliminated. It was also selected for its high strength to weight ratio, for its natural and sustainable qualities and for its aesthetic appeal. It is joined together with high strength, low alloy structural steel to form composite bowstringing beams in a form that allows each material to participate in a way that best suits its nature.



The steel tie bars, or bowstrings, generally operate in tension, although they are proportioned to accommodate load reversal under fluctuating conditions of wind. The glulam bowed beams behave in one sense as beams in the resistance of shear and flexure and also as tied arches. Oval steel sections were selected for the compression struts of the tree branches and for the vertical struts of the bowstring beams.

Fig. 5b Twin beams with twin tie rods

Lateral stability is achieved through moment resisting frame action, or portal action to carry load down to the concrete structure. In the direction parallel to the bowstring beams, it is the beams and tree columns that act as a double portal, partially fixed at the base of the tree branches, while in the longitudinal direction steel beams concealed above the metal ceiling working with the tree branches achieve stability through portal action. The portals are fixed to the supporting RC columns by semi rigid connections. The end result is a building containing two movement joints running continuously in the eastwest direction intersecting with the service cores and separating the roof into three independent and self supporting structures

3.3.2 Material Selection

At concept stage materials were selected on the basis of engineering efficiency as well as aesthetic appeal and sustainable credentials. The roof structure is a series of twin Glulam beams (215mm wide x 1035mm deep), which cross the building in two spans of 40 metres.

3.3.3 Design Loads

Several hundred load cases were investigated in respect of anticipated conditions of service for ultimate and serviceability limit states.

The roof is intended to be a lightweight cover protecting the terminal from the elements and in this respect is meant to be as light as practicable. But under high wind loads the potential exists for uplift effects of wind suction to exceed the dead load due to gravity. Under conditions of uplift, the compression in the timber is greatly reduced and small compressions will be present in the steel tie rods, so the rods are also designed to withstand those small compressions, with restraint provided by the compression struts.

3.3.4 Connection Design

Detailed connection design was made the responsibility of the Contractor, who employed specialist subcontractors for this work. However, because connection design is so important in timber design, outline design was carried out for all primary connections to verify capacity of the glulam beams.

This connection was designed to cater for load imbalance associated with the sequential erection of glulam/steel bowstring assemblies onto the tree columns and these forces were communicated to Jacobs who were designing the supporting structure. The connection design concepts were developed by the Contractor's designer, Peter Bertsche (*Fig. 6*) and then reviewed for adequacy to resist anticipated loads and conformity with the aesthetic intent. As the roof structure comprised both structural timber and structural steel in roughly equal measure in a single structural package, the question of who would take the lead in connection design was by no means a foregone conclusion. As it turned out, the Contractor's timber provider, Derix, took the lead subcontractors' role and retained Peter Bertsche to carry out the detailed design of all timber and steelwork

connections. Derix also appointed Bruninghoff to carry out the fabrication of the steelwork and timber connections and the erection of the roof structure (*Fig. 7 and 8*).

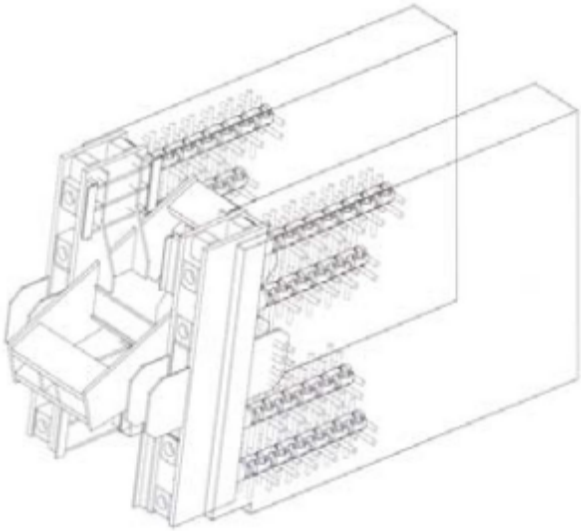


Fig. 6 Timber Splice Connection Detail by Bertsche

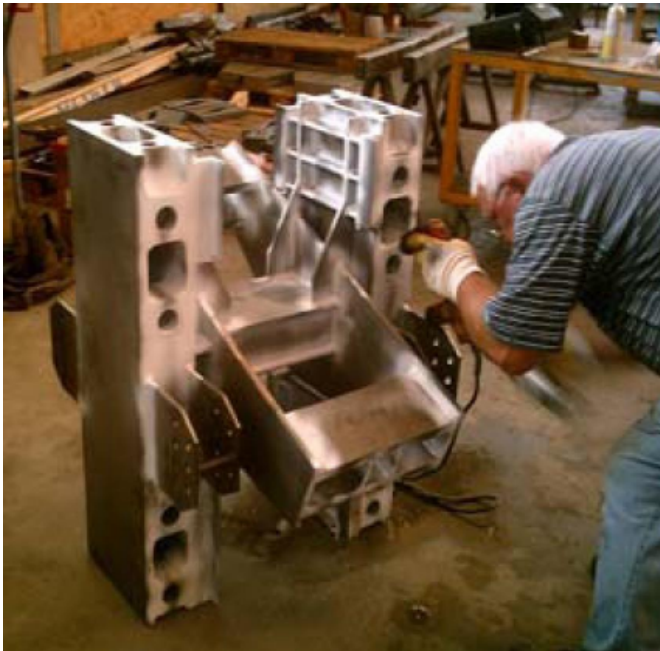


Fig. 7 Weld inspection of splice connection at Bruninghoff Fabrication



Fig 8 Connection on site

3.3.5 Dominant openings

BS 6399 Part 2 contains recommendations for the treatment of dominant openings in the design of the building envelope. Of concern is the nature and magnitude of internal pressures and the resulting overall wind effects on a building. While the departure entrance is conditioned with the use of a vestibule, diminishing its effect as a dominant opening, the entrance has nevertheless been treated as a dominant opening for the serviceability limit state in the interest of robustness.

3.3.6 Movement

Owing to a combination of factors anticipated roof structure movements at the interfaces with other systems are relatively large in comparison to other building structures. Contributing parameters include relative long cantilevers at edges, long main spans, lightweight form of construction, relatively high exposure parameters in relation to wind and the use of a moment resisting frame for lateral load resistance instead of a more rigid shear wall or braced frame type of system.

3.3.7 Erection

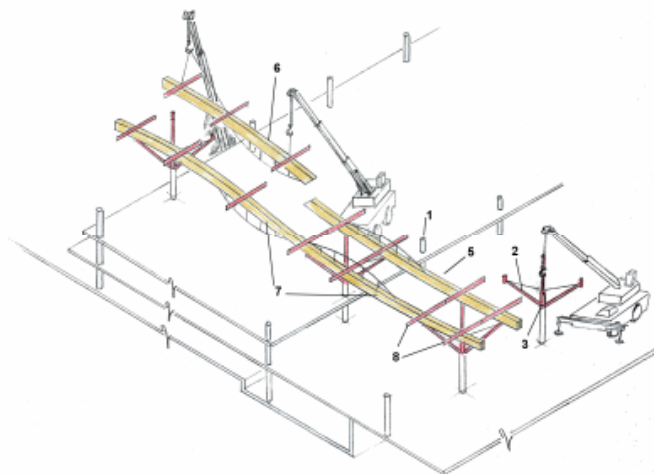


Fig. 9 Axonometric illustration of Roof Erection Concept

As the design evolved, timber and steel beams spanning 90 metres across the terminal building raised issues including the length of beam that was practical to fabricate and transport to site, sequencing the connection of timber and steel bowstring assembly with the erection, splicing the bowstring beams, the size and weight of the pre-assembled components and the temporary conditions of loading and stability of partially completed structures, which is of particular importance for the tree structures. These issues in our opinion are rightly dealt with in an envisaged erection sequence and an accompanying risk assessment.



Fig. 10 Transportation from Derix works in Germany



Fig. 11 Roof Erection

While anticipated structural movements remain within reasonable limits of structural performance, the main concerns at the design stage were in relation to interfaces with other systems. Estimated movements were reported in the structural drawings to ensure they could be coordinated with and accommodated by other building systems. In particular, careful attention was given to reporting movements along perimeter façade systems and movement joints, where façade structure subsystems and architectural weather protection details are critical

From the very early days of scheme design we concerned ourselves with developing a solution that took into account the erection of the roof structure (*Fig. 9*).

Ultimately, the Contractor chose an erection sequence that matched the one we envisaged using similar methods (*Fig. 10, 11*), but the specification required the Contractor to develop the detailed erection method as it was his expertise, operatives and equipment which ultimately were responsible for the successful erection of the roof structure.



Fig. 12 Finished Building

4. References

- [1] Dahdouh S; Bakkala C. "Cork Airport Terminal Development" Engineers Ireland 25/05/2006